A Reanalysis Synthesis of EOS Observations at Regional Scales to support the National Climate Assessment

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- Assimilated data sets that synthesize and integrate the existing satellite (and conventional) data streams for the EOS/Aura period – an enabling tool
- Specialized products to support the NCA
- Builds upon the ~50 km reanalysis for the satellite era generated as the Modern-Era Retrospective analysis for Research and Applications (MERRA).

➢ Use of MERRA for NCA applications

Status:

- Submitted a technical report for input to the NCA 2013 report
- Extracted regional and sector-specific products for use in the NCA
- ~ 250 products available at ftp://gmaoftp.gsfc.nasa.gov/pub/data/mikeb/NCA/

➢ Perform a 25km GEOS-5 analysis that improves upon MERRA for NCA applications:

Status

- System now finalized: includes new data streams (IASI & GPS-RO are in 25 km NRT system; MLS & OMI tested in proof of concept exps)
- Includes aerosol analyses (Now in 25 km NRT system)
- MLS and OMI data have been downloaded and re-formatted for assimilation ingest
- Land-surface analyses (planned) will be in the next implementation

MERRA-Land Reanalysis:

- A supplemental and improved set of land-surface hydrological fields, including soil moisture, snow, and run off - corrects some limitations of MERRA in a land-only post-processing system.
- Documented in GMAO Office Note No. 3 (http://gmao.gsfc.nasa.gov/research/merra/MERRA-Land_Documentation_20120412.pdf)
- Now available at the GES DISC.

MERRA-Ocean Reanalysis

- MERRA-forced ocean reanalysis is available through a Live Access Server (LAS) on the NCCS data portal [http://dp6.nccs.nasa.gov/las/].
- The next implementation will be served through the NCCS iRODS

The new observations

- **IASI and GPS-RO**
  - Improve tropospheric analyses
  - Impact can be measured through forecast skill
- **MLS temperature profiles,** p < 5hPa
  - Improves temperature structure throughout the stratosphere
  - Affects use of radiances in the analyses – affects the troposphere as well as the stratosphere
  - Affects computations of chemical feedbacks
- **MLS ozone profiles (V2.2) and OMI total column ozone (V3)**
  - Important in Radiative Forcing
  - Lower stratospheric and upper tropospheric ozone dominates
- **MLS water vapor,** p < 240hPa
  - Solomon et al. (Science 2010) argue that stratospheric moisture plays an important role in climate forcing

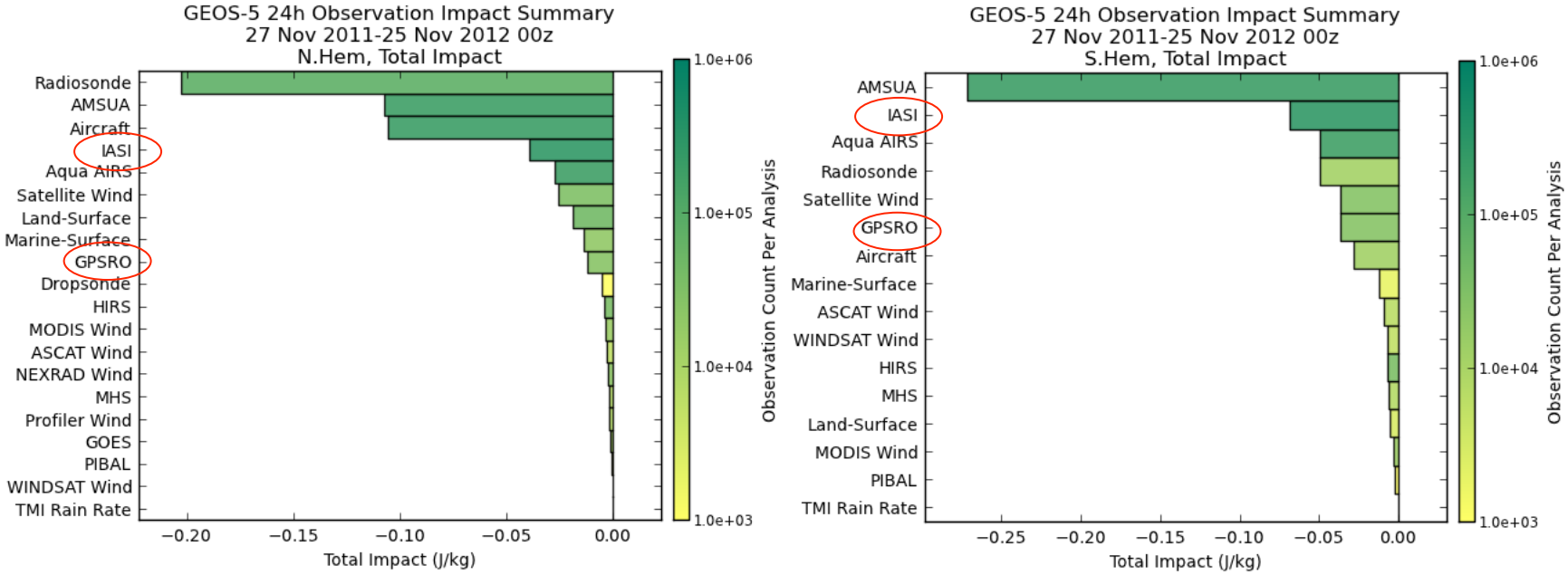
Research quality retrievals are not available in real-time, so most appropriate for reanalyses

Proof-of-Concept Experiments

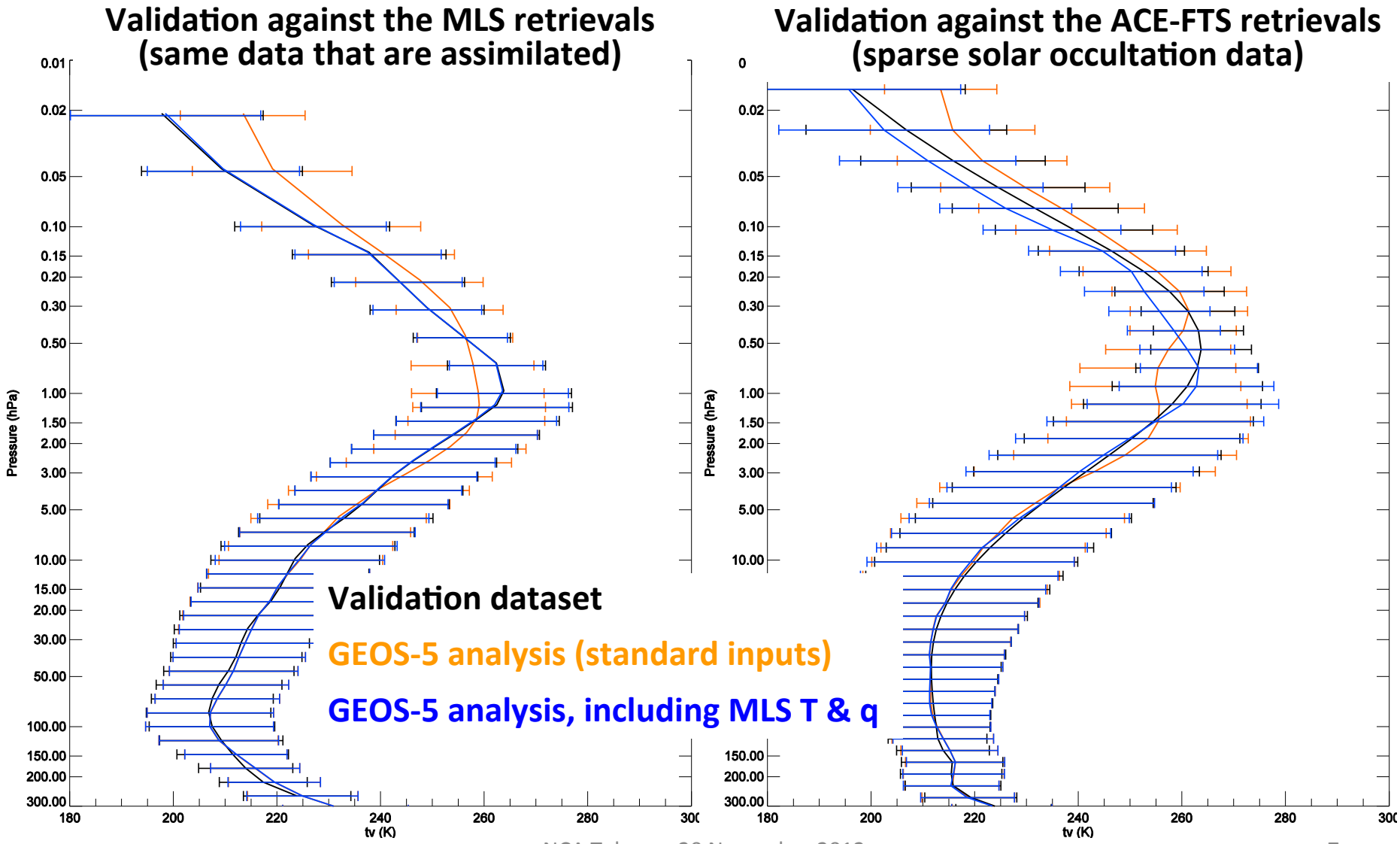
- Period: 2005-2007
- GEOS-5, Version 5.7.2
  - Baseline includes GPS-RO, IASI, and recent ATOVS data not used in MERRA
  - Improved background error variance formulation for ozone (reduces smearing across the tropopause)
  - Enhanced to include MLS and OMI observations
- Low-resolution (2°×2.5° L72) system in these tests
- Changes have been ported to GEOS-5, Version 5.9.1, for 25 km NCA reanalysis
  - Version 5.9.1 includes Suomi-NPP observations (ATMS)

Temperature Data in GEOS-5

- Radiances from ATOVS (AMSU-A, HIRS), EOS-Aqua (AMSU-A, AIRS), IASI, ATMS
- Conventional observations (sondes, aircraft, …)
- GPS-RO bending angle
- MLS v3.3 retrievals for p < 5hPa
- IASI and GPS-RO improve analyses – as seen in forecast impacts (MERRA already sees the benefit from assimilating AIRS)



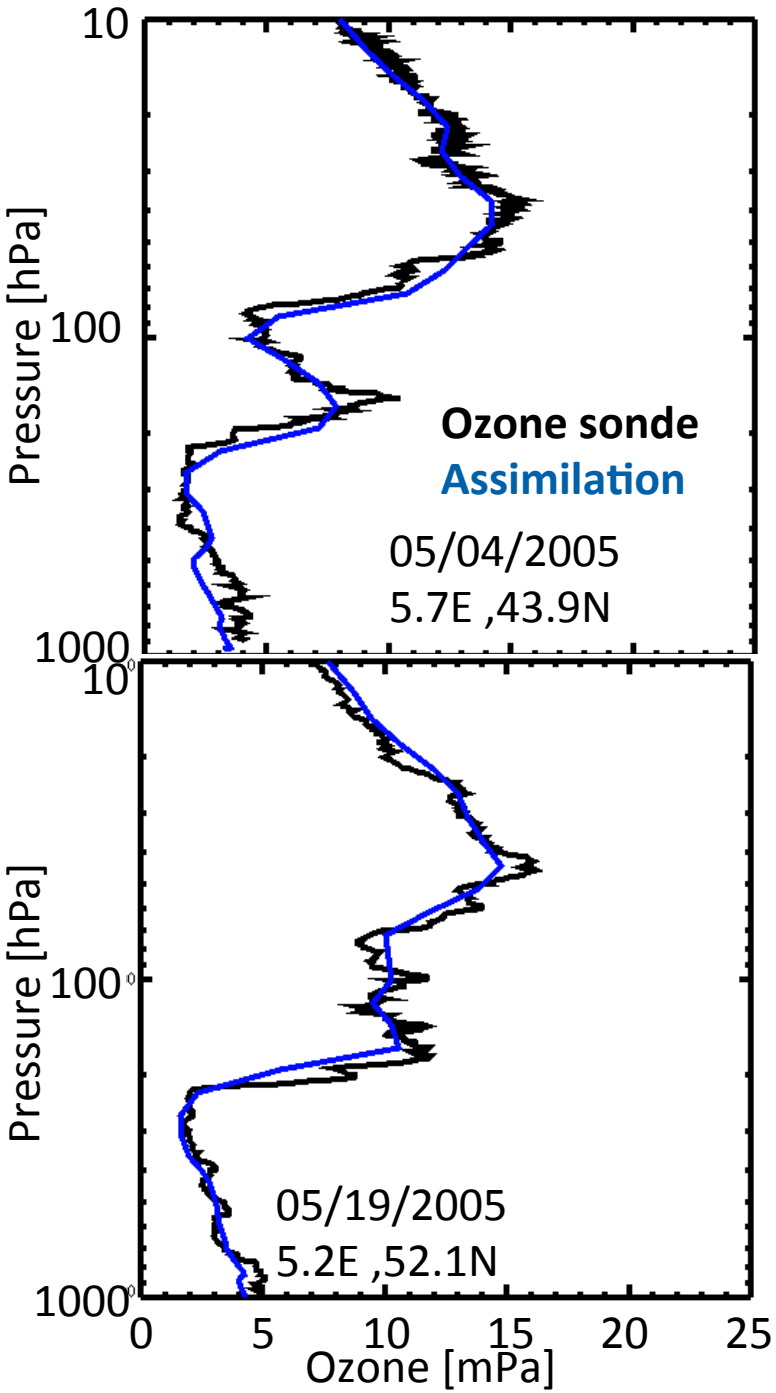
Validation of the global-mean temperature (subsampled at observation locations) in July 2005, compared to MLS and ACE-FTS



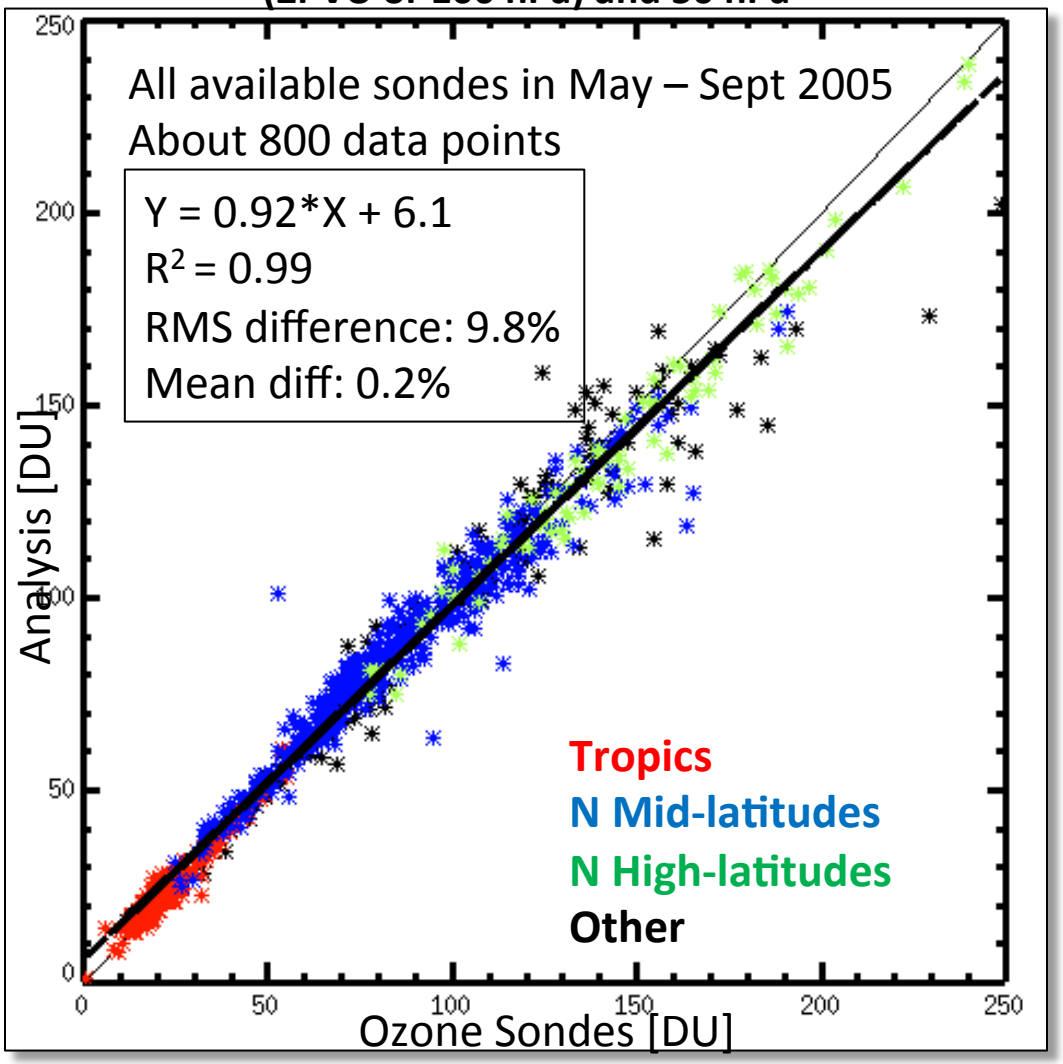
Error bars are one standard deviation of global data at observation locations.

Ozone

- Observations used in analysis:
  - OMI total column Version 3 retrievals
  - MLS v2.2 retrievals
- Background error covariance updated from MERRA:
  - Inflated vertical length scales (reduced noise)
  - Error variance proportional to local background ozone
- Model chemistry updated from MERRA:
  - Dry deposition mechanism at the surface – diurnal cycle
  - Production rates and loss frequencies in the stratosphere
  - Parameterized chemistry turned off in the troposphere



Ozone integrated between the tropopause (2PVU or 100 hPa) and 50 hPa



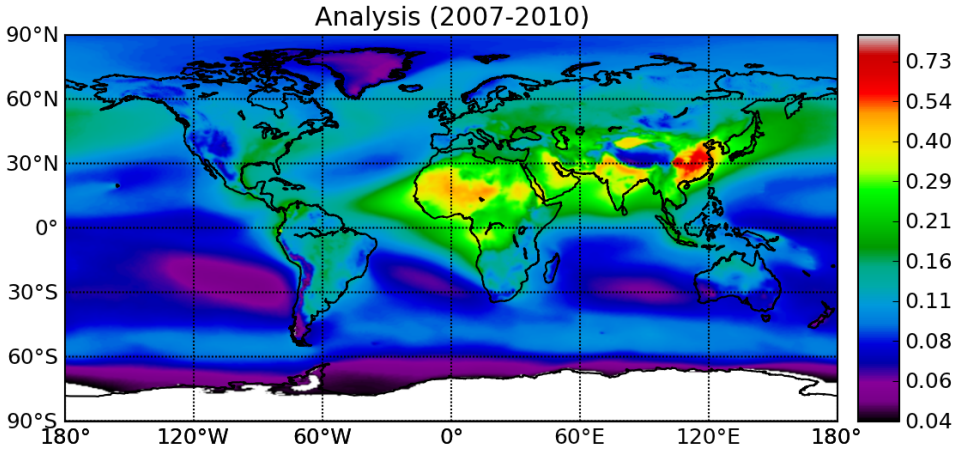
Excellent agreement of the MLS+OMI analysis with ozone sondes in the lower stratosphere in terms of ozone abundances, variability, and vertical structure.
Note: sondes have random errors of up to 10-15%

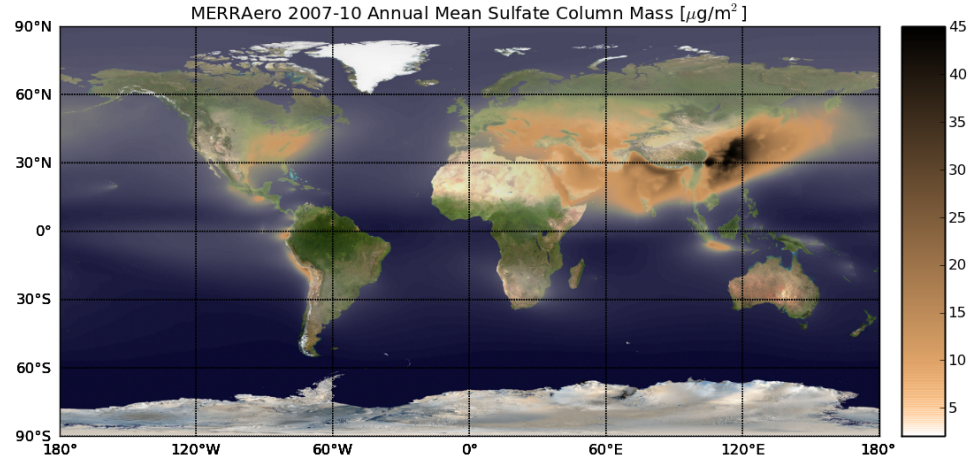
Summary of MLS enhancements for the NCA reanalysis

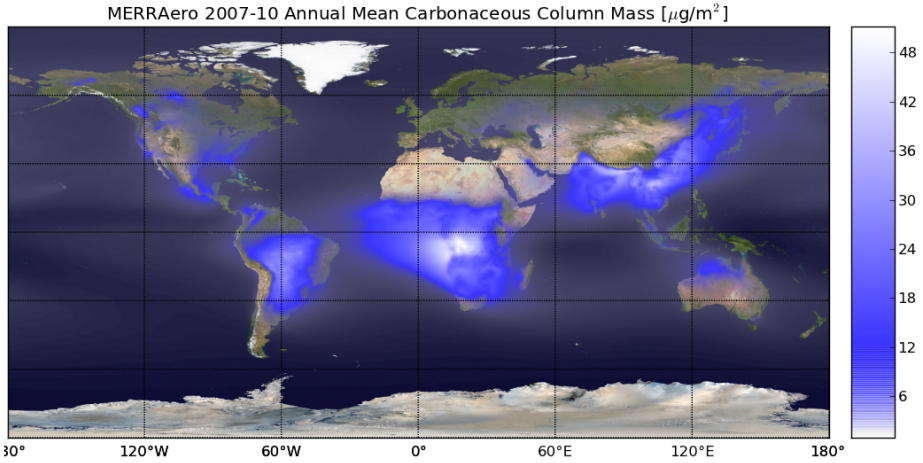
- MLS temperature and ozone can now be assimilated into GEOS-5
- Stratopause thermal structure is substantially improved over standard system
- GEOS-5 draws strongly to MLS ozone at all layers – improvements (over MERRA, using SBUV) in the UTLS
- MLS moisture retrievals had little impact - the full impact is inhibited for technical reasons (choice of moisture variable) – and will not be included in the NCA reanalysis
- In MERRA, stratospheric moisture was strongly constrained by an imposed climatology – the baseline model has been updated

MERRAero: MERRA-based aerosol assimilation

An aerosol re-analysis for 2003-2012
Aerosol assimilation now used in the GEOS-5 NRT system and will be used in the NCA reanalysis, with aerosols feeding into the radiation calculation.

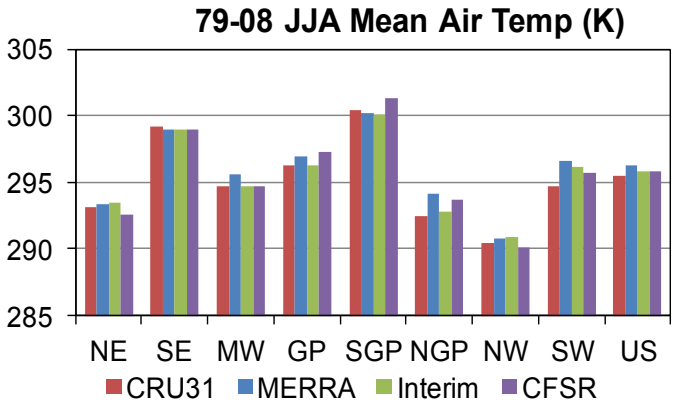


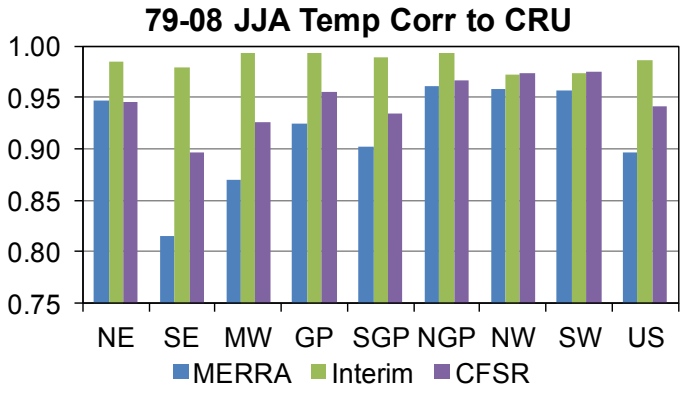




MERRAero assimilates MODIS observations and uses volcanic and biomass-burning emissions derived from MODIS fire radiative power. While the annual mean analyzed AOD (top) reflects the MODIS AOD it assimilates, the derived annual mean column mass of sulfates (bottom left) and carbonaceous aerosols (bottom right) provide context to the measurements.

Near-surface atmospheric temperature (T2m)





MERRA: Many summertime biases are less than 1K, and none more than 2K.

The correlation between reanalyses and observed time series are also quite high.

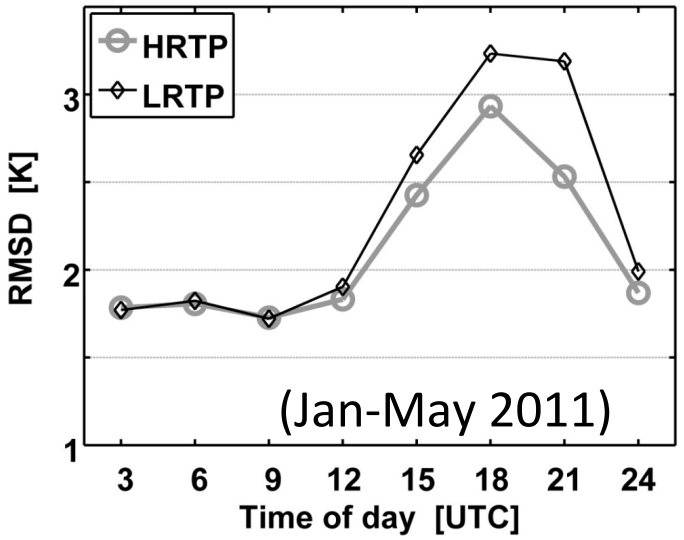
However, MERRA does not perform as well as the other reanalyses because they use other observations to constrain the land skin temperature and soil moisture.

Hence the plan to link the GEOS Land analysis with the atmospheric analysis. Focus is on Land Surface Temperature (LST) retrievals from geostationary satellites (to resolve the diurnal cycle).

Tskin assimilation

Progress so far:

- GEOS-5 LST compared with LaRC Tskin retrievals from GOES-13, Jan – May 2011.
- Initial comparisons with 1° GOES retrieval; transitioned to 0.25° product and comparisons (RMSD) improved.
- GEOS-5 LST typically warmer than obs during nighttime and much cooler during daytime. Will address bias as part of the assimilation system, but need a longer time series (Reichle et al., 2010).
- Have now received LaRC data for all of 2011 and will use this to develop a bias correction.



Scarino et al., *Rem. Sens.*, 2012 (submitted)

Publications and Presentations

Bosilovich, M. G., 2013: Regional Climate and Variability In NASA MERRA and Recent Reanalyses: US Summertime Precipitation and Temperature. Submitted to *J. Appl. Met. and Climatol.*

Scarino, B., P. Minnis, R. Palikonda, R. Reichle, D. Morstad, C. Yost, B. Shan, and Q. Liu, 2012: Retrieving Surface Skin Temperature for NWP Applications from Global Geostationary Satellite Data. Submitted to *Remote Sensing.*

Pawson, S., J. Jin, L. Coy and K. Wargan, 2012: Impacts of Assimilating MLS Temperature on the Upper Stratosphere in GEOS-5. *Aura Science Team Meeting* Pasadena, CA, October 1-3, 2012

Wargan, K., S. Pawson, M. Olsen, A. Douglass, J. Witte, S. Strahan, and N. Livesey, 2012: Global Assimilation of EOS-Aura Data as a Means of Mapping Ozone Distribution in the Lower Stratosphere and Troposphere. *Aura Science Team Meeting* Pasadena, CA, October 1-3, 2012

Jin, J., S. Pawson, K. Wargan, and M. Sienkiewicz, 2012: Constraining Middle Atmospheric Moisture in GEOS-5 Using EOS-MLS Observations. *U.S. - Japan Bilateral Workshop on the Tropical Tropopause Layer: State of the Current Science and Future Observational Needs,* Honolulu, Hawaii, October 15-19, 2012

Bosilovich, M.G., F.R. Robertson and J. B. Roberts, 2013: Regional Climate and Variability of the Summertime Continental United States in Reanalyses. *Applied Climate Data Analysis Session, 20th Conference on Applied Climatology*, Austin TX, 9 January 2013.

Future Plans

- NCA production will focus first on 2010-2011 and catch up to climate-RT
- Expect to begin production in mid-Dec [final check-out of cubed-sphere version of analysis to speed processing is underway]; 2010-2011 production will take ~4 months.
- Continued developments: LST and MLS moisture
- After evaluation of 2010-2011 analysis, we will re-initiate an analysis for 2005-present.

Summary

- NCA system has now been finalized and input data have been pre-processed
- IASI and GPS-RO data improve tropospheric analysis
- MLS ozone and temperature retrievals and OMI column ozone improve stratospheric analysis significantly on the current production system which improves significantly upon MERRA
- Land skin temperature assimilation is not mature enough to include in this version

- NCA production from 2010 will begin mid-December.